6.0 Basic Data Acquisition and Topographic Mapping [11-19-2003]

PURPOSE

To acquire and assemble the basic physical data needs for the study in a consistent GIS for use by all study participants. Basic data needs include the following data sets:

a. Physical features inventory for the entire Yellowstone River corridor developed by NRCS and available on the NRIS Yellowstone data home page at: http://nris.state.mt.us/yellowstone/

b. Land cover and land use inventory for the entire Yellowstone River corridor [developed by NRCS in 2001(?)].

c. Aerial photography for the entire Yellowstone River corridor (if available) or at least covering the approximately 200-250 river miles of detailed studies. Dates for the aerial photography data sets will be determined by the PDT and TAC early on in the study process. It is anticipated that approximately 6 sets of historic and current aerial photography will be acquired, scanned, and digitally rectified to allow easy comparison between the various years. Known sets of aerial photography that already are (or will be) digital are the 2001 NRCS CIR aerials and the new 2005 hi-res CIR or full-color aerials acquired as part of the topographic mapping. At least one set of aerials will be acquired from each of the following ranges of years: the earliest available complete (or near complete) set, likely 1940's or early 1950's; 1950-1960; 1960-1970; 1975-1985; 1985-1995. Additionally, a set of aerial flood photography from the 1997 flood event in Stillwater and Yellowstone Counties, and a full set of COE aerials from 1973(1976 for USACE photos on the upper Yellowstone) will be acquired and processed. All of the aerials will be scanned and digitally rectified to match the 2001 CIR aerials (new 2005 hi-res CIR or full-color?).

d. Detailed topographic mapping of the entire Yellowstone River corridor. The topographic mapping will consist of 2-foot accuracy surveys (4-foot contour interval) of the entire Yellowstone River floodplain and adjacent corridor lands, and 1-foot accuracy surveys (2-foot contour interval) of the channel bathymetry (beneath the water surface) in the detailed study reach areas with a total length of approximately 250 river miles.

REQUIRED STUDY TASKS

6.1 River Channel Physical Features Inventory Review and Verification

Purpose

To assemble, review, verify, and supplement existing data as needed from the NRCS physical features inventory. The new orthophotos acquired as part of the topographic data will be used for review and precise identification of river channel features as to type and location.

Required Sub-Tasks

1. **Acquire physical features inventory.** Acquire physical features mapping from the NRCS and NRIS.

2. **Review and check the data.** In the reaches selected for detailed analyses, spot check features mapped to determine if ~~extra~~ continued effort using high-resolution aerial photos would materially improve cumulative effects analyses of current river uses.

3. **Document any gaps.** Identify any gaps in river feature coverage ~~or uses mapped~~, with particular emphasis on the locational accuracy of channel and floodplain modifications. ~~such as sensitive environmental areas, cultural areas, erosion areas, river access, water diversions, etc…~~

4. **Indicate any necessary revisions.** Make necessary revisions to the existing mapping as required for the study, and make results available to all studies.

Estimated Cost: $9,800 (assume $7,600 labor, $2,600 travel and per diem)

Staff Contact: CE Study Manager and District Hydraulics staff

6.2 Land Use and Land Cover Data and Review

Purpose

To review, verify and supplement existing data as needed from the NRCS and YRCDC land cover/land use inventory. To complete hydraulic and geomorphic analyses, subdivisions and individual, residential and recreational developments smaller than 10 acres will require identification and classification. ~~In addition, acquisition of the new orthophotos may aid in the review.~~ The new orthophotos acquired as part of the topographic data will be used for review and precise identification of river channel features as to type and location.

Sub-Tasks:

1. **Acquire land use / land cover data.** Acquire land use/cover mapping from the NRCS.

2. **Review and check the data.** In the reaches selected for detailed analyses, spot check features mapped to determine if extra effort using high resolution aerial photos would materially improve cumulative effects

analyses of current river uses, including riparian habitat, Phase II geomorphology and floodplain delineation studies.

3. **Document any gaps.** Identify any gaps in ~~river features or~~ land use coverage relevant to the cumulative effects analyses, such as sensitive environmental areas, important infrastructure, cultural resources, etc.

4. **Indicate any necessary revisions.** Make necessary revisions to the existing mapping as required for the study, and make results available to all studies.

Estimated Cost: $4,900 (assume $3,600 labor, $1,300 for travel and per diem**)**

Staff Contact: CE Study Manager and District GIS staff

6.3 Aerial Photography Acquisition

PURPOSE

Aerial photography will be utilized by all of the technical studies to aid in evaluating how the Yellowstone River corridor has changed over time and help to establish trends and linkages for the cumulative effects study. The purpose of this task is to acquire numerous sets of historic aerial photography and convert them to a digital format for use in a GIS. The aerial photography data sets will be selected to span over the 50-plus years from the 1930's and 40's to the 1990's. Utilization of numerous aerial photography data sets is essential to span the variety of historic flow conditions that could have influenced any particular single set. For example, photos in years immediately following a year of prolonged high flood flows may over exaggerate the bare sandbar and/or bank erosion activities when compared to photos from years of more moderate or even low flows. The goal is to acquire sufficient historic aerial photography to represent a reasonable cross-section of the history of the River spanning the last 50 or so years. The PDT and TAC will select the dates for the aerial photography data sets early on in the study process. The objective would be to acquire complete aerial photography sets covering the entire Yellowstone River corridor (if available) or at least covering the approximately 200-250 river miles of detailed studies that will be used in the overall CES. For budgeting purposes, it is anticipated that approximately 6 sets of historic and current aerial photography will be acquired, scanned, and digitally rectified to allow easy comparison between the various years. The index data set that will be used to register the digital images will be the 2001 NRCS CIR aerials. At least one set of aerials will be acquired from each of the following ranges of years: the earliest available complete (or near complete) set, likely 1940's (possibly 1930's); 1950-1960; 1960-1970; 1975-1985; 1985-1995. Additionally, a set of aerial flood photography from the 1997 flood event in Stillwater and Yellowstone Counties, and a full set of COE aerials from 1973(?) will be acquired and processed.

Sub-Tasks:

1. **Select dates for aerial photography.** Meet with PDT and TAC following geomorphology phase I to finalize selection of dates for the historic aerial photography.

2. **Scan and rectify photos.** Scan and digitally rectify 6 sets of historical aerial photography, including 1976 COE complete set, 1997 flood aerials for Stillwater and Yellowstone Counties, at least 1 additional complete set, approximately 200-250 river miles from 3 other years, and the 1997 flood aerials for Stillwater and Yellowstone Counties. The digital aerials will be rectified to the Montana State Plane projection with a datum of North American Datum 1983 (NAD83) in units of meters.

3. **Quality Assurance/Quality Control (QA/QC)**

   a. PI Quality Control (QC).
   The PI will develop a Quality Control Plan (QCP) to outline review procedures for study products/deliverables. The QCP should include a description of the QC process, outline of interim review milestones, names and qualifications of reviewers, and an example of comment/issue resolution. The QCP will be submitted by the PI and approved by the Corps and TAC prior to initiation of the technical study. At the end of the study, the PI will complete a QC Report that documents the interim peer reviews (i.e. comments and responses).

   b. Quality Assurance (QA).
   A QA review will be performed to ensure that the PI has met the objectives of the scope and has followed the approved QCP. The QC Report will be reviewed to insure that all comments have been addressed. This QA review will be conducted by the Corps and the TAC.

4. **General Expenses.** These cost include the direct cost of accessing various GIS software, hardware and databases, and the use of CADD resources such as workstations, printers, and plotters.

Estimated Cost: Estimated total cost for acquiring, scanning, and digitally rectifying aerial photography will be approximately $147K wow?. Assumptions: photo resolution – 1:24,000; photo size – 8” x 8”; photo overlap – 25%; number of river miles per photo – 2 river miles; scanning unit cost – $10 per photo; digitally rectifying unit cost – 3 hours @ $50/hour => $100; total cost per river mile - $80.00/river mile (rounded up).

2 Complete Sets – 450 mi. (1976 & TBD): $36,000 (450 mi. @ $80 / mi.)
4 Partial Sets – 250 mi. (TBD): $80,000 (1,000 mi. @ $80 / mi.)
Metadata Documentation (~5%): $6,000
QC/QA review (5%): $6,000

Travel and Per Diem: $5,400 (assume 2 trips, 2 persons, 3 days each w/ rental car)
General Expenses (10%): $14,000.

Staff Contact: CE Study Manager and District GIS staff

6.4 Topographic Mapping Acquisition

PURPOSE
Obtain spatial data necessary to develop detailed topographic information, provide orthophotographic support for development of DTM's, and mapping/inventory of physical features, river channel structures and habitat and connected wetlands in the flood plain. This data will support hydraulic, geomorphic, biologic, river structures inventory, permit location and land use inventories. The study area is approximately 700 square miles, or a 1.55 mile wide corridor along the river channel for a distance of 450 miles. The color orthos are based on a negative scale of 1"=1667 ft., suitable for high resolution ortho-photo production (1 ft pixels). Topographic information will be collected by a LIDAR approach at a 4-foot contour level of accuracy. Detailed bathymetric (underwater channel) data (2-foot contour interval) will be collected along the thallweg in selected reaches by river surveys to a 1-foot depth. This will be merged with the LIDAR data for development of the DTM's.

Sub-Tasks:

1. **Finalize detailed study reaches for bathymetric surveys.** Meet with sponsor and advisory groups following Phase I geomorphology to firm up estimate land area to be covered by mapping.

2. **Develop contract scopes of work.** Develop draft and final scopes of work to contract the photographic and LIDAR and SONAR work with a single contractor. The contract will include necessary work to develop a topographic DTM in order to provide a continuous surface model in DTM/TIN formats. The DTM will meet NMAS (National Map Accuracy Standards) and will use a coordinate system and datum of Montana State Plane, North American Datum 1983 (NAD83), North American Vertical Datum 1988 (NAVD88) units of meters.

3. **Advertise and award contract.** After scope review and approval by the Corps and sponsor, advertise and select contractor.

4. **Monitor work progress.** Review work scope with contractor and periodically monitor progress of contractor by reviewing interim products

5. **Quality Assurance/Quality Control (QA/QC).**

a. PI Quality Control (QC).
The PI will develop a Quality Control Plan (QCP) to outline review procedures for study products/deliverables. The QCP should include a description of the QC process, outline of interim review milestones, names and qualifications of reviewers, and an example of comment/issue resolution. The QCP will be submitted by the PI and approved by the Corps and TAC prior to initiation of the technical study. At the end of the study, the PI will complete a QC Report that documents the interim peer reviews (i.e. comments and responses).

b. Quality Assurance (QA).
A QA review will be performed to ensure that the PI has met the objectives of the scope and has followed the approved QCP. The QC Report will be reviewed to insure that all comments have been addressed. This QA review will be conducted by the Corps and the TAC.

6. **Distribute final survey results.** Package the survey information and distribute to PDT and TAC for utilization by other technical studies.

7. **General Expenses**

a. Supervision and Administration.
This task includes supervision of the employees working on the study, and administration cost such as contract management, clerical support, etc.

b. GIS and CADD Cost.
These cost include the direct cost of accessing various GIS software, hardware and databases, and the use of CADD resources such as workstations, printers, and plotters.

Estimated Cost: Estimated total cost for topographic surveys (incl. LIDAR and bathymetry) will be approximately $1.0 – $1.1 Million.
Detailed color orthophotos: $210,000 (700 sq. mi. @ $300/sq. mi.)
Detailed 4-foot LIDAR mapping: $606,200 (700 sq. mi. @ $866/sq. mi.)
Detailed 2-foot channel bathymetry: $272,500 (250 mi. @ $1,090/mi.)
Contract scoping, advertising and selecting, and oversight: $7,200
QA/QA review (1%): $11,000.
Travel and Per Diem: $2,600 (assume 2 trips 2 days each w/ rental cars).
General Expenses (2%): $22,000.

Staff Contact: William Schwening, CE

Contractor: May be a Best Value Selection from Corps Preferred Contractors

Yellowstone River Cumulative Effects Study
Basic Data Acquisition SOW Budget 7-Jan-04

	Task 1	Task 2	Task 3	Task 4	Task 5	Total
Total Costs	**$10,500**	**$6,500**	**$118,000**	**$805,000**	**$238,000**	**$1,178,000**
Contract Labor, Benefits, ODC	$0	$0	$75,000	$315,000	$223,000	$613,000
DNRC Labor, Benefits, Indirect, ODC	$1,500	$1,500	$3,000	$5,000	$3,000	$14,000
USCOE labor, benefit, indirect, ODC	$9,000	$5,000	$15,000	$35,000	$10,000	$74,000
YRCDC In-kind (Rec Dev Grant)	$0	$0	$25,000	$250,000	$2,000	$277,000
Co. Floodplain Mgmnt (Ren Res Grant)	$0	$0	$0	$200,000	$0	$200,000
Non-Federal Cost Share	**$1,500**	**$1,500**	**$28,000**	**$455,000**	**$5,000**	**$491,000**
DNRC Labor,Benefits, Indirect, ODC	$1,500	$1,500	$3,000	$5,000	$3,000	$11,000
YRCDC In-kind (Rec Dev Grant)	$0	$0	$25,000	$250,000	$2,000	$277,000
Co. Floodplain Mgmnt (Ren Res Grant)	$0	$0	$0	$200,000	$0	$200,000
Other Federal Share	**$0**	**$0**	**$0**	**$100,000**	**$0**	**$100,000**
FEMA Yellowstone Co. FIS $'s	$0	$0	$0	$100,000	$0	$100,000
Federal Cost (Corps)	**$9,000**	**$5,000**	**$90,000**	**$250,000**	**$233,000**	**$587,000**

Task Descriptions	**Deliverables**
1 Physical Features Data Review	See PMP Appendix A
2 Land Use Data Review	See PMP Appendix A
3 Historic Aerial Photography Acquisition	2 complete sets ~ 450 riv.mi.(1976 & 1940's or 1950's), 4 partial sets ~ 250 riv.mi.
4 Topographic Mapping Acquisition	hi-res color orthophotos & 4-ft LIDAR topo ~ 700 sq. mi.
5 Channel Bathymetry	2-ft bathymetry ~ 250 riv.mi.

Note - Contract labor = $75 per hour; USCOE labor = $100 per hour; DNRC labor = $25 per hour

7.0 Information Management and GIS Development (11/25/03)

PURPOSE

The purpose of this component of the overall scope of work is to provide a means to communicate information and results of the project to the public, the Council, and investigators working on the project. The objectives are several:

- Provide database design and data development services to individual work plan components so as to facilitate an integrated, interdisciplinary cumulative effects analysis.

- Provide electronic data storage and retrieval capabilities (data hosting and clearinghouse functions) during the life of the project and beyond;

- Provide a means for information and data sharing amongst scientific investigators responsible for individual work plan components;

- Provide Internet access to final products resulting from the project;

- Provide map rendering services to assist in communicating results in the Plan Formulation/Cumulative Effects Assessment phase

IMPORTANT CONSIDERATIONS

Integrated Database Approach: Use of GIS capability to organize and analyze datasets is an integral element of most work plan components. Principal investigators are responsible for securing GIS and information management/processing services necessary to complete their scopes of work (e.g., historic photo scanning and rectification within the geomorphology scope) and, if necessary, updating their respective datasets into the future (e.g., weed distribution). Beyond generating discipline-specific information, it is desirable to devise a means to integrate the variety of geospatial information so that it may be examined in an interdisciplinary context (a la cumulative effects assessment) in an effort to identify critical linkages across disciplines (e.g., economic productivity and geomorphic channel type, or channel type and weed distribution, etc.) Toward this end, a task has been included to assist in the design, development and implementation of an integrated database and GIS system that would provide users a comprehensive and standardized repository of information collected and generated as part of the project. This database system would also support sophisticated user interface systems that would allow for various types of spatial and tabular queries, data and map views, and data extraction and distribution.

Need for Information Management Services: Two primary information management needs have been identified: distribution and data sharing needs of those working on the project itself (internal usage); and clearinghouse and query services necessary to transmit products and results to end users and the public (external usage). For the former, data and information posted and shared may be technical, preliminary and subject to revision. As such, distribution needs to be limited to project workers and possibly password protected to prevent the spread of misinformation. For clearinghouse services, results of the investigation that are final products should be made accessible to interested parties via the Internet through user interface and query systems. Clearinghouse posting needs may include aerial imagery, digital terrain models, weed distribution mapping, vegetation/habitat results, channel type classification, demographics, land use, flood hazard, etc. Timely clearinghouse data hosting is necessary to support ongoing and future federal, state and local regulatory and planning efforts within the corridor. The success of the clearinghouse is dependent on the integrated database approach outlined above, and the premise that the data will be hosted at a site that can guarantee reliable, stable, and long-term service. As part of the State Library, Montana's Natural Resource Information System (NRIS) can provide this type of service and guarantee. The project will benefit greatly by being able to leverage against the very substantial data, web, and GIS infrastructure that NRIS already possesses.

<u>Dataset Parameters</u>: Initially, three primary datasets will require management and distribution: LiDAR results, bathymetric results, and color orthophotography. Minimum deliverables from the contractor would be provided in either TIN (triangulated irregular network) and/or DTM (digital terrain model) format. Color orthophotos with a 1-foot ground resolution and a vector file containing topographic contours, which are necessary to add precision to feature locations and to develop topographic break lines for the contouring of the DTM, will be included in the remote sensing contract deliverables. The terrain models (including the subaqueous topo) and orthophotos are necessary to support the hydraulic modeling and geomorphic analyses. Public use and distribution of the remote sensing data (LiDAR or orthophotos) and the bathymetric results, or products derived thereof, would not be subject to licensing restrictions as per contract specifications with the selected vendor.

The extent of the project area has been determined as part of the geomorphology reconnaissance scope of work. Gross estimation of 500-year floodplain extent indicates an area of approximately 700 square miles. Assuming a 700 square mile mapped extent, the <u>currently identified</u> electronic data storage requirements are:

- <u>color aerial imagery</u> ~ 70 gigabytes (.tif file type). Total dataset size may be reduced to ~ 7 gigabytes via the use of MrSID compression techniques; *although compressed imagery is not as suitable for many applications as the TIFF format, this project will require both formats;*
- <u>Topographic contour file</u> ~ 4 gigabytes (vector file only); and
- <u>TIN or DTM</u> ~ 12 gigabytes (suitable for use with ESRI software).

Additional storage may be needed to house results derived from various project components: bathymetric results, cross section files, vegetation mapping results, valuation data from the economic analysis, habitat delineation, inundation boundaries, etc. Costs associated with providing 50-100 gigabytes of storage are approximately $5,000 - $10,000 for high speed, fail-over protected, fiber-based storage, integrated into a Storage Area Network (SAN). For budgeting purposes, the storage requirement for this project is estimated to be 1 gigabyte per river mile or approximately 500 gigabytes. A cost estimate of $20,000 has been included in the budget to acquire this amount of server capacity.

Distribution of Duties: For purposes of allocating costs associated with internal versus external data distribution needs, data distribution services would be divided as follows: the Corps would be responsible for operating an internal data distribution and sharing network (similar to that used on the upper Yellowstone investigation) for workers within the project -this service would continue throughout the anticipated four-year life of the project; the Montana State Library, NRIS would be responsible for operating and maintaining the external information clearinghouse, and for tasks associated with public/Council user interfacing, including the significant educational responsibility of presenting outreach material to stakeholders. This service has commenced with the data hosting and user interface development associated with the Physical Features Inventory, and will continue into the future beyond the duration of the project. This work would include periodic updating and maintenance of the physical features inventory currently accessible through the NRIS website.

Geospatial Data Documentation and Format: All geospatial datasets developed through individual scopes of work must meet ArcView versions 3.X through 8.X. In other words, there must be backwards compatibility between datasets developed using ArcView 8.X and ArcView 3.X software. Geospatial data deliverables will not be considered final and available for external posting until supplied with Federal Geographic Data Committee compliant metadata (*FGDC, 1998, Content Standard for Digital Geospatial Metadata*). Principal Investigators shall be responsible for ensuring data developed under their respective scopes of work are in compliance. NRIS shall review all incoming datasets for metadata completeness and adequacy prior to external posting. Any contract developed to acquire remotely sensed data (i.e., LiDAR and color orthophotos) shall include specifications that require provision of metadata in compliance with the FGDC metadata content standard including any applicable extensions pertaining to remote sensing. **Geospatial data products associated with individual work components shall be delivered in Montana State Plane Coordinates, NAD 1983 in units of meters.**

Quality Assurance/Quality Control (QA/QC): NRIS will develop a Quality Control Plan (QCP) to ensure that products meet the requirements of the scope. The QCP will include as a minimum a description of the QC process, listing of review milestones, names and qualifications of reviewers, and an example of comment/issue resolution. The QCP will be submitted and approved by the Corps and Council prior to initiation of work. As part of the QC process interim peer reviews will be performed at specified milestones through the study process as outlined in the QCP. At the end of the study, NRIS will complete a QC Report that documents the execution of the QCP. A Quality Assurance (QA) review will be performed to ensure that NRIS has followed the QCP. The Corps and the Council will conduct this QA review.

Task 7.1 — Provide database design and consulting services

Objective: Ensure consistency for database design across disciplines. This will allow organization of geospatial data so that a variety of information may be displayed through geographic query capabilities (e.g., river mile and/or county). Examples of attribute fields include: physical features; land use; channel type, etc.

Responsibility: NRIS through contracted services with USOCE

Deliverables: Relational database with interdisciplinary geographic query capabilities (e.g., a user could select a reach of the river and get a display of economic activity supported by all diversion points within that reach or a user could select a reach of the river and get a display of multi-threaded channel types within highly erosive soil types).

Task 7.2 — Internal data hosting services

Objective: Operate and maintain hardware (server capacity) and software (remote uploading and downloading capability) so as to provide information and data sharing capabilities amongst investigators working on the project.

Responsibility: USCOE

Deliverables: manage and maintain 100 gigabytes (minimum?) server storage space plus distribute software necessary for access.

Task 7.3 — Provide external data hosting services

Objective: Ensure delivery of data products with the widest utility possible. In addition to data posting and providing public user interface capabilities, this would include any necessary post processing activities of spatially referenced data sets (i.e., reprojection, compression (MrSID), and tiling/mosaicing of image files); and review of contract specifications for data products such as products derived from the LiDAR dataset and color orthophotos.

Responsibility: NRIS through contracted services with USCOE

Deliverables: State of the art, comprehensive, project data

Task 7.4 — Maintenance of the physical features inventory

Objective: Update and maintain the physical features inventory currently available via the Thematic Mapper on the NRIS site (shape files, functional evaluation database, photographic links, etc.) NRIS would receive, process and post updates periodically (quarterly?). This work includes periodic (annual?) meetings with the Council and its TAC to review progress and discuss website changes.

Responsibility: NRIS under contract to Custer CD; Conservation Districts via 310 applications; RAMES database updating process currently in effect (quarterly).

Deliverables: Updated physical features inventory.

Task 7.5 Provide metadata review services

Objective: This task serves as a final check on documentation for geospatial products resulting from individual work components.

Responsibility: NRIS through contracted services with USCOE

Deliverables: FGDC compliant metadata for all geospatial datasets made available for external posting to the Internet.

Task 7.6 Provide Map Rendering Services

Objective: As needed, provide hard copy graphics to aid in communicating results of the cumulative effects assessment process, and to assist in developing Best Management Practices in the Plan Formulation Phase.

Responsibility: NRIS under contract to USCOE and by direction from the Council and its TAC.

Deliverables: As requested by the project team

Task 7.7 Provide Training and Education

Objective: As necessary, provide training to the Council, conservation districts, the TAC and other interested parties with respect to database capabilities and web data access (see Tasks 7.1 and 7.3).

Responsibility: NRIS under contract to USCOE and by direction from the Council and its TAC.

Deliverables: Lectures and training materials

Task 7.8 Quality Control

Objective: Ensure that the study products meet the requirements of the scope

Responsibility:	Quality Control: NRIS; Quality Assurance: Corps and Council
Deliverables:	1) Quality Control Plan; 2) Quality Control Report

Yellowstone River Cumulative Effects Investigation
GIS Services and Information Management 11/24/2003

	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Total
Total Costs	**$14,952**	**$4,000**	**$49,172**	**$11,969**	**$14,836**	**$14,836**	**$7,668**	**$2,151**	**$119,584**
USCOE Labor,Benefits,Indirect	$0	$4,000	$0	$0	$0	$0	$0	$0	$4,000
USCOE direct costs	$10,752	$0	$41,504	$8,602	$10,752	$10,752	$5,376	$1,613	$89,351
DNRC Labor, Benefits	$1,000	$0	$500	$500	$500	$500	$500	$0	$3,500
NRIS Labor, Benefits, Indirect	$3,200	$0	$7,168	$2,867	$3,584	$3,584	$1,792	$538	$22,733
Non-Federal Cost Share	**$4,200**	**$0**	**$7,668**	**$3,367**	**$4,084**	**$4,084**	**$2,292**	**$538**	**$26,233**
DNRC Labor & Benefits Cost Share	$1,000	$0	$500	$500	$500	$500	$500	$0	$3,500
NRIS Labor, Benefits, Indirect	$3,200	$0	$7,168	$2,867	$3,584	$3,584	$1,792	$538	$22,733
Federal Cost	**$10,752**	**$4,000**	**$41,504**	**$8,602**	**$10,752**	**$10,752**	**$5,376**	**$1,613**	**$93,351**

Task Descriptions	**Deliverables**
1 Provide database design & consulting services	
2 Provide internal data hosting services; USCOE cost covered in project contingency	
3 Provide external data hosting services; COE direct cost includes $20,000 data storage hardware	
4 Maintain physical features inventory	
5 Provide metadata review services	
6 Provide map rendering services	
7 Provide education and training	
8 QA/QC	
NRIS hourly rate = $35.84 (includes 40% indirect charge)	
NRIS cost share calculated at 25% of personnel services	

8.0 Channel and Flood Plain: Hydrology [11-17-2003]

PURPOSE

The purpose of this study is to develop the hydrologic data necessary to evaluate the water related problems in the Yellowstone River basin. Results of the hydrology study will serve as the foundational basis for understanding the Yellowstone River ecosystem and for making decisions regarding sustainability. The primary objective of the hydrology analysis is to establish the discharge frequency and flow duration relationships for the Yellowstone River from Park County to the confluence with the Missouri River near Williston, ND.

Establishing the discharge frequency relationships will first involve extensive effort in developing unregulated flows and regulated flows for a long-term period of record at each of the main stem gaging stations. Once the unregulated and regulated hydrographs are developed, the annual peak discharges will be selected for use in the discharge frequency analysis. Development of unregulated flows and regulated flows for a long-term period of record is a significant task for the Yellowstone River because of the extensive water development that has occurred in the basin. Daily flow hydrographs will be developed through model studies for both unregulated and regulated flow conditions. Adjustments or refinements may be required to the simulated flow hydrographs based on judgment and past operating experience. Regulated flow conditions will include the current level of water resources development and flood control regulation on the tributaries.

The overall goal of the hydrology study is to determine the ecologically sustainable hydrologic condition of the Yellowstone River and compare that condition to the existing condition. In order to achieve this goal, the hydrology study is designed to provide answers to the following questions:

a. What are the Yellowstone River's historic stream flow trends and what are their causes?

b. How much water does the system generate and how does the system's natural variability affect the river's ability to meet its intended uses?

c. What effect do control mechanisms such as Yellowtail Dam, Tongue River Dam and the major irrigation projects have on the amount of water available for the complete range of intended uses?

d. What is the ecologically sustainable hydrologic condition of the Yellowstone? In other words what are the hydrologic conditions necessary to maintain its level of productivity, allow it to function with minimal external management, and repair itself when stressed?

e. How does the current hydrologic condition of the Yellowstone compare with the naturally occurring or ecologically sustainable condition?

Ancillary goals of the hydrology study include providing basic hydrologic information to other study components. In order to determine the ecologically sustainable condition, the hydrology component must be integrated with the biology and socioeconomic components of the study. For example, flow frequency (annual probability of flow exceedance) and flow duration (percent of time a given discharge is exceeded) analyses provides information on the magnitude of flow events, and their annual probability and duration of occurrence. This information can be translated into depth and velocity for any given point along the river through hydraulic analysis. This information is useful to a number of disciplines including hydraulic engineering (floodplain delineation and structure design and siting), geomorphology (sediment transport and erosion potential), and riparian ecology (habitat evaluation).

REQUIRED STUDY TASKS

1. **Basin Reconnaissance.** This effort shall involve a site reconnaissance investigation by the hydraulic engineers conducting the study. The site reconnaissance will be made near the initiation of the study to become familiar with the study area and conduct an initial meeting with the Yellowstone River Conservation District Council. During the site reconnaissance, the physical features of the basin and streams shall be reviewed to collect hydrologic data for inclusion into the hydrologic and hydraulic models. Particular attention shall be focused on drainage pathways, diversions, soil characteristics, overflow areas, bridges, culverts, and other basin features that could impact flow conditions. Cross sections and roughness coefficients for the channel routing reaches will be estimated during the site reconnaissance

2. **Basin Wide Hydrologic Model**. Because of the extensive development of water resources in the Yellowstone River basin for irrigation, hydropower, and other uses, the stream flow regime has changed over time. A basin wide hydrologic model will be configured and utilized to develop a homogeneous flow record for both regulated and unregulated flow conditions. The “Regulated” flows will represent the flows that would have occurred historically if the existing (today’s) water resources development had been in place. The “Unregulated” flows are those that would have occurred if no water resources development had occurred in the basin. This task will also include researching and reviewing the USBR estimates of depletions in the Yellowstone River basin. Comparisons of historical estimates will be made with depletion estimates used in the MBSA database. Meetings with the USBR to gain an understanding of the methodology used to develop the estimates will be included as part of this task. Adjustments to the basin depletion estimates may be required depending on the outcome of this review. An HEC-HMS model will be configured for the entire Yellowstone River basin. HEC-HMS is a hydrologic precipitation runoff and routing model developed by the Corps Hydrologic Engineering Center. Digital maps in the form of Digital Elevation Models (DEM) will be downloaded from the USGS web site and used with the geo-HMS ArcView extension to configure the HEC-HMS model. Recorded daily stream flow data will be downloaded from the USGS web site and stored in an HEC-DSS database. The period of record to be used for analysis is 1928 through 2002, a 75 year record length. Some stream gages have records available as early as the late 1800’s but the records are sparse. Some of the stream gages do not have records extending to 1928 and will require

filling in the records by interpolation or synthesis. Meteorological data including precipitation, temperature, snow water equivalent, and evaporation will be downloaded from the NOAA and NRCS archives and stored in an HEC-DSS database. Soils information will also be obtained from the NRCS. The HEC-HMS model will also be configured to simulate the operation of major tributary reservoirs including Yellowtail, Boysen, and Tongue. The model will be calibrated to reproduce historic flows. Once the model is calibrated it will be used to develop a period of record of Regulated and Unregulated flows. Future use of the model could also include flood forecasting and evaluation of future project alternatives including additional basin storage, change in existing reservoir operation, and changes in irrigation demands throughout the basin.

3. **Develop Seasonal Flow Duration**. Flow duration relationships are used to define the percent of time that a given discharge is equaled or exceeded. Duration curves represent the cumulative distribution function of all data recorded at the site, which can be based on annual or seasonal periods. Seasonal duration curves can be defined to represent particular months or seasons such as the fall low flow or spring and summer runoff season. A duration curve is not a probability curve. It should not be interpreted on an annual event basis because it provides only the fraction of time that a given event was exceeded and not the annual probability of an event occurring. It can be used to determine the average number of days per year that a particular magnitude is equaled or exceeded if it is annual duration curve or the number of days during a particular month or season if it is a seasonal duration curve. Daily or monthly data can be used to develop a duration curve. A shorter time step in the data used will typically result in a duration curve with steeper slopes at the extremes. Duration curves are developed using class interval analysis. Class interval analysis involves subdividing the data into defined class intervals and computing the relative frequency of each class interval based on the number of data within each class. USGS Stream flow records at all main stem gaging stations and at the mouths of major tributaries will be used to develop monthly and annual flow duration relationships. These relationships will be developed for the total period of record and various periods over time using the HEC-STATS computer program. Flow duration relationships will also be developed using the Regulated and Unregulated flows developed as part of the basin wide hydrologic modeling in task 2. Computed flow duration relationships will be summarized in tables and illustrated graphically.

4. **Develop Flow Frequency Relationships**. Once the annual peak discharges are developed for each year of the period of record for unregulated and regulated conditions, a discharge frequency analysis of those data will be completed. Annual peak discharges for the Regulated and Unregulated conditions will be used to derive the Regulated-Unregulated relationships. The Regulated flow frequency curve will be based on the Unregulated Flow Frequency curve and the Regulated versus Unregulated flow relationships. Graphs will be prepared to display the annual peak flow data along with the computed frequency curves. Depending on the results of the analysis, additional statistical analysis may be required. Regulated flows during recent floods such as 1995, 1996 and 1997 will be used to verify the regulation effects on the unregulated frequency curve. Following completion of the discharge frequency analysis the results will be used to prepare discharge profiles from Park County to the mouth. Impacts of major

tributaries and attenuation will be considered when developing the profiles. Supplemental studies of coincidence and routing may be required to develop the final profiles. Graphs will be prepared that display the peak discharge versus river mile for frequency profiles including the 0.2, 1, 2, 10, 20, 50 and 67 percent chance exceedance profiles. Gage locations, major tributaries, and other significant locations will be noted on the graphs.

5. **Develop Volume Probability Relationships**. Volume probability relationships will be derived for the main stem and tributary gages. Two sources of flow data will be used. The first will consider the historical flows recorded at the USGS stream gages for the period of 1928 through 2002. These records will be retrieved from the USGS database and stored in an HEC-DSS file. The second source of data will be obtained from the hydrologic model simulation of regulated and unregulated flows. These simulated daily flows will be stored in an HEC-DSS file. Next the HEC-STATS computer program will be used to develop the volume-probability relationships for durations of 1-, 3-, 7-, 15-, 30-, 60-, 90-, 180-, and 365-days. Statistics will be smoothed by plotting mean versus standard deviation for the various durations analyzed. Smoothing of the statistics is necessary to prevent the extrapolated curves from crossing. Skew coefficients will be adopted based on computed station skew coefficients, Beard’s standard skew coefficients, and inspection of observed annual events and computed frequency curves. Final adopted volume probability relationships will be based on the curves derived from the two sources of data.

6. **Develop Balanced Flood Hydrographs**. Once the Volume Probability relationships are computed in task 5, Balanced Design Flood Hydrographs will be constructed for various frequency events. They will be patterned after the historic flood hydrographs from major runoff events in 1996 and 1997. At each stream gage a balance flood hydrograph will be developed for historic, regulated, and unregulated conditions. Relationships between unimpaired flows and regulated flows will be derived for various flood durations and used to develop the regulated volume duration frequency curves

7. **Examine Storage Effects of Yellowtail**. During public scoping, significant public comment was directed at the effects of flow releases from Yellowtail Reservoir, particularly with respect to flood damages and channel morphology. Therefore, this task will include using the hydrologic model developed in task 2 to evaluate the effects of storage in Yellowtail on flows along the main stem downstream of the confluence with the Big Horn River. This evaluation will include both changes in existing release patterns and the addition of more flood control storage at the Yellowtail site. Information in previous studies will be reviewed and incorporated into this task. Previous studies include the Yellowstone Impact Study, Technical Report No 2, published in 1977, by the DNRC and a report by Womack Associates published in 2001.

8. **Report Preparation**. A detailed technical report will be prepared to document the study objectives, data used, methodologies, results and conclusions of the study. Charts and tables will be prepared to summarize the results and compare the evaluations of the

historical, regulated and unregulated flow regimes. Assumptions used in the hydrologic model will be discussed. Graphs of discharge frequency relationships and flood hydrographs will be prepared for each stream gage along the main stem of the Yellowstone River as well as at the confluence of major tributaries. Maps showing the locations of river reaches, stream gages, cities, major tributaries, major reservoirs, existing levees, basin boundaries, and other important locations shall be prepared. Bar graphs and tables shall be prepared to show the annual peak discharges for each year for unimpaired, regulated, and observed conditions at each gaging station. Daily stream flow hydrographs for each year and each condition shall be plotted at each gaging station and included in an appendix to the report. Discharge-frequency curves and discharge profiles shall be prepared and illustrated graphically and in tabular form in the report. Sources of data used in the analysis shall be referenced in the report.

9. Meetings & Coordination. This task will include in-house meetings with the study team as well as meetings with the Yellowstone River Conservation District Council. It is anticipated that there will be at least six meetings with the Council during the course of the study.

10. Quality Assurance/Quality Control (QA/QC).

10.1 PI Quality Control (QC).
The PI will develop a Quality Control Plan (QCP) to outline review procedures for study products/deliverables. The QCP should include a description of the QC process, outline of interim review milestones, names and qualifications of reviewers, and an example of comment/issue resolution. The QCP will be submitted by the PI and approved by the Corps and TAC prior to initiation of the technical study. At the end of the study, the PI will complete a QC Report that documents the interim peer reviews (i.e. comments and responses).

10.2 Quality Assurance (QA).
A QA review will be performed to ensure that the PI has met the objectives of the scope and has followed the approved QCP. The QC Report will be reviewed to insure that all comments have been addressed. This QA review will be conducted by the Corps and the TAC.

11. **General Expenses.** General expenses include fees for the use of ArcView, the Geographical Information System (GIS) network, GIS personnel, and plotter will be collected, as these tools will be used while the product is being developed. All GIS data will include metadata and will be projected in Montana State Plane with a horizontal datum of North American Datum 1983 (NAD83) and a vertical datum of North American Vertical Datum 1988 (NAVD88) [units meters].

Yellowstone River Cumulative Effects Study
Hydrology SOW Budget 1/7/2004

	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Task 9	Task 10	Task 11	Task 12	Total
Total Costs	**$11,425**	**$185,285**	**$13,388**	**$35,700**	**$26,775**	**$22,313**	**$31,238**	**$24,813**	**$41,775**	**$28,000**	**$16,000**	**$18,000**	**$454,712**
USCOE Labor,Benefits,Indirect	$8,925	$180,285	$13,388	$35,700	$26,775	$22,313	$31,238	$22,313	$26,775	$15,000	$16,000	$0	$398,712
USCOE direct costs	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$12,000	$12,000
DNRC Labor, Benefits, Indirect, ODC	$2,500	$0	$0	$0	$0	$0	$0	$2,500	$5,000	$8,000	$0	$2,000	$20,000
USBR Labor, Benefits, Indirect, ODC	$0	$5,000	$0	$0	$0	$0	$0	$0	$5,000	$0	$0	$2,000	$12,000
USGS Labor, Benefits, Indirect, ODC	$0	$0	$0	$0	$0	$0	$0	$0	$5,000	$5,000	$0	$2,000	$12,000
Non-Federal Cost Share	**$2,500**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$2,500**	**$5,000**	**$8,000**	**$0**	**$2,000**	**$20,000**
DNRC Labor & Benefits Cost Share	$2,500	$0	$0	$0	$0	$0	$0	$2,500	$5,000	$8,000	$0	$2,000	**$20,000**
YRCDC Cash	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
Other-Federal Funds	**$0**	**$15,000**	**$0**	**$5,000**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$20,000**
FEMA Yellowstone Co. FIS $'s	$0	$15,000	$0	$5,000	$0	$0	$0	$0	$0	$0	$0	$0	**$20,000**
Federal Cost (Corps)	**$8,925**	**$170,285**	**$13,388**	**$30,700**	**$26,775**	**$22,313**	**$31,238**	**$22,313**	**$36,775**	**$20,000**	**$16,000**	**$16,000**	**$398,712**

Task Descriptions	**Deliverables**
1 Basin Reconnaissance (fieldwork)	see ACOE project management plan - inlcudes DNRC assistance
2 Develop Basin-Wide Hydrologic Model	see ACOE project management plan - includes cost for USBR providing depletion estimates
3 Develop Seasonal Flow Duration Curves	see ACOE project management plan
4 Develop Flow Frequency Curves	see ACOE project management plan
5 Develop Volume Probability Relationships	see ACOE project management plan
6 Develop Balanced Flood Hydrographs	see ACOE project management plan
7 Examine Storage Effects of Yellowtail	see ACOE project management plan
8 Report Preparation	see ACOE project management plan - includes 100 hrs DNRC tech review
9 Meetings & Coord (internal, external)	DNRC, USBR, USGS, and Corps attendance and participation at meetings
10 QA/QC	COE 4% of ~ $380K, USGS $5,000, includes 320 hrs DNRC (Robinson)
11 GIS administration (4%)	
12 Travel, per diem, ODC	ACOE, USBR, USGS, DNRC

9.0 Channel and Flood Plain: Hydraulics [11-18-2003]

PURPOSE

The proposed hydraulic analyses tasks are to provide hydraulic information required to define the current and historic extent of the Yellowstone River floodplain for the purpose of identifying opportunities to reduce flood damages, determine impacts from human development, and restore environmental features and functions. Secondary purpose would be to provide detailed hydraulic data including river stages, velocities, flow depths, and flooded areas that may be useful in the geomorphic and biologic analysis for the study.

The following questions will be addressed:

a. What is the current extent of the Yellowstone River floodplain? What was the historic extent of the Yellowstone River floodplain?

b. Where and to what extent has human-included floodplain modifications affected floodplain functions such as floodwater storage, energy dissipation, erosion and sediment transport characteristics?

c. Where do opportunities exist for combined flood damage reduction and environmental restoration projects?

These purposes and questions were used in determining the primary tasks outlined in this scope of work. The following paragraphs provide a general overview of these tasks and how they relate to the study purposes and questions. Following the general overview, the hydraulic tasks are described in more detail.

The first hydraulic task is to prepare a hydraulic model providing approximate hydraulic analysis in the form of water surface profiles and flood inundation areas for the 10-year, 100-year and the 500-year flood events along the Yellowstone River from its mouth to the Park County line (this task will provide approximate modeling for about 300 miles of the about 460 miles study area miles). This “developed” conditions (existing conditions) model will address the intent of question (a).

The second hydraulic task is to provide a detailed hydraulic model for water surface profiles, flood inundation areas, and floodways to identify areas subjected to a flood hazard along about 92 miles along the Yellowstone River. Areas identified include three in Stillwater County (Park City, Columbus, and Reed Point – three 5 mile long sections between RM 389 to 394, RM 410-415, and RM 430 to 435, a 58-mile reach in Yellowstone County from the western county boundary to about Pompey’s Pillar (RM 327 to 389), and a 15-mile reach in Dawson County in the Glendive area (RM 84-99). Please note these are the Corps regulatory river miles. Only the areas requested by local officials will be submitted to FEMA for Flood Insurance Study (FIS) purposes. For these reaches detailed hydraulic models will provide the base data required for producing Flood Insurance Study flood hazard mapping. This detailed study effort will address question (a) and to help identify any opportunities for flood reduction and environmental restoration as stated in question (c).

The third hydraulic task is to analyze the impacts of human development and will consist of two parts. The first part is to analyze the effect of man-made structures and encroachments on the Yellowstone River hydraulic profiles and flood boundaries. The second part is to analyze the effect of man-made storage, diversions, and depletions on the Yellowstone River hydraulic profiles and flood boundaries. The results of this task will address the second part of question (a).

The fourth hydraulic task will be to provide detailed hydraulic information (in the detailed study reaches) for more frequent flows for the geomorphic and biologic analyses. Prior to the start of the hydraulic analysis, these detailed reaches will have been identified. This 100-mile reach is assumed as a separate reach from the detailed study reach described for flood hazard mapping for estimating purposes. (For scoping purposes, it is assumed 25 miles of the detailed analysis for FIS purposes reach overlaps 25 miles of this reach for geomorphic and biologic detailed modeling resulting in a total of 150 miles for total detailed analysis). In these reaches, detailed HEC-RAS models will be developed for geomorphology and biology data. Data calculated by the detailed HEC-RAS models (velocity, depth, channel slope, topwidth, etc) will be used in the detailed geomorphology study for the stream for developed conditions. Both the undeveloped and unregulated water surface profiles and flood inundation mapping will be recomputed for these new detailed study areas. This information will be useful in determining the impacts from human development on the river. In addition, more frequent flood events will be modeled to provide information on frequent flood stages, river velocity, and river depth. This information will help address question (b).

The final hydraulic task will be to look at existing opportunities for environmental restoration. One currently identified opportunity is to provide fish passage at dams on the Yellowstone River. One such potential project is the Cartersville Irrigation Diversion Dam at Forsyth. Detailed mapping will be obtained for this study area to allow an investigation into the potential alternatives for fish passage at this location. The scope of work allows for an additional investigation to be conducted at another location later in the study. This task will help address question (c).

REQUIRED STUDY TASKS

Hydraulic Analysis. The hydraulic analysis assumes a Digital Terrain Model (DTM) as a Triangulated Irregular Network (TIN) would be delivered that would allow cross sections to be taken from the terrain surface model. The terrain (or surface) model is assumed to include both overbank and underwater (hydrographic) surveys, providing an all-inclusive surface model and topographic contours of the channel and overbank survey areas. The topographic survey and mapping scope of work will describe the acquisition and accuracy of this data in more detail.

1. **Research Files and Literature Review.** A review of Corps of Engineers (COE) files, past studies, and other available literature pertaining to hydrologic studies for the Yellowstone River will be performed. The search will look specifically for high water marks, ice thickness and jam information, bridge data (obtained from federal, state, and local agencies), and riverine structure (dams and diversions) information (the structure inventory included in this study will be used as a reference). A search for other hydraulic

analyses will also be performed specifically for Flood Insurance Studies to allow a comparison of those studies to this study.

Additional data requirements include researching and documenting historical flood data that can be used to help calibrate the hydraulic models. It is anticipated that historical flood data collection and documentation would be performed by a local entity or the project sponsor and is included as work-in-kind in the cost estimate. For estimating purposes, the amount of effort required to research historical data with local newspapers, disaster and emergency services offices, Montana Department of Transportation, etc… is assumed to be approximately a total of 30 days or 6 weeks. Also, the Montana Department of Natural Resources and Conservation and/or local entities will provide supplemental survey information on local structures such as high water marks, levee crest profiles, road and railroad embankments profiles, diversion dams, etc… Again this effort is included as work-in-kind and for estimating purposes, the effort for providing the supplemental survey information is assumed to be approximately 100 miles of road/railroad embankments and/or levees that would be surveyed at a unit cost of $115 per mile.

2. **Additional Data Collection.** The mapping will have a 4-foot contour interval for the entire Yellowstone River corridor from the Park-Stillwater County line to the mouth. This means the accuracy for a spot elevation on levees and roadway embankments will be plus or minus 2 feet. Additional bridge and levee surveys will be scoped to provide better elevation accuracy on these embankments as they will be integral to the hydraulic modeling effort. The need for additional surveys will be based on whether they occur in a detailed or approximate study reach. Data that would be needed for all bridge data include: a centerline bridge deck elevation at both ends of the bridge, bridge width, distance measurements for the bridge span(s), number and width of piers, low chord elevation for the bridge, depth of bridge deck, and a picture of the bridge opening. In addition, any visible high water marks from the 1997 flood will be identified, photographed, coordinates documented, and the elevation surveyed. This data will be used in calibrating the HEC-RAS model for large flood events. For bridges located in the detailed study reach, additional data will include the surveying of three water surface elevations. This will include one elevation upstream and downstream from the bridge (will use field judgment, but will be approximately 800 feet upstream and downstream) and an elevation near the bridge. This data is only required in the geomorphic and biologic reaches for calibrating the model for low flow conditions. In the approximate detail reaches, additional data required will include a minimum of two channel cross sections. One channel cross section under the bridge and one cross section upstream or downstream from the bridge. Again the location of the cross section or the need for a third cross section will be based on field judgment but will be located approximately 800 feet upstream or downstream from the bridge. For estimating purposes, approximately 60 bridges will need to be surveyed and it is assumed about 20 to 30 high water marks will be surveyed. The United States Geological Survey provided the costs for the 1997 high water marks and bridge surveys.

3. **HEC-RAS Model Setup.** HEC-RAS assumes steady, gradually varied flow in natural or man-made channels. The effects of various obstructions such as bridges, culverts, weirs, and structures in the flood plain are considered in the computations. The computational procedure is based on the solution of the one-dimensional energy equation with energy loss from friction evaluated with Manning's equation. The computational procedure is generally known as the standard step method. The DTM or TIN model generated from the survey will be used to generate cross sections for the HEC-RAS model using the ArcView extension HEC-GeoRAS. The accuracy of the HEC-RAS model (cross section geometry) will depend on the accuracy of the mapping provided. The model work will be done in two levels of detail – detailed and approximate. There is about 450 miles along the Yellowstone River in the study area. About 200 miles of the Yellowstone River will be done as a detailed study and the remaining 250 miles will be done as an approximate study. For both efforts the 55 bridges in the study reach will be included in the HEC-RAS model. The model will utilize the results of the "regulated" and "unregulated" discharges described in the Hydrology scope of work. The channel centerline alignment as well as river mileage will have been provided from the geomorphology phase I work and will be a basis for the Geo-RAS procedures used in setting up the HEC-RAS model. ***Please note that tributaries to the Yellowstone River will not be modeled as a part of this anlaysis.***

   a) **Detailed Study.** A centerline for the Yellowstone River will be drawn as well as right and left bank stations and cross sections using HEC-GeoRas. Cross section spacing will average about 500 to 1000 feet apart with closer spacing near structures and areas of specific interest. Data on the bridges crossing the river (obtained in steps 1 and 2) will be coded into the HEC-RAS model. Specific structures such as diversion dams will be modeled in the HEC-RAS model using available survey information. Roughness values for the channel and overbanks will be assigned to the HEC-RAS model. Using high water mark data collected in steps 1 and 2, the HEC-RAS model will be calibrated to historic flood events.

   b) **Approximate Study.** The description of the detailed study will be followed for the approximate study, but the cross section spacing will be increased to about 2000 feet apart to decrease the amount of effort involved in creating and calibrating the model. Additional cross sections will be included in the bridge areas to improve the model at bridge locations. Only major channel structures will be modeled (for example diversion dams). The data obtained in steps 1 and 2 will be used to model the bridges. The results from the calibrated HEC-RAS model will be compared to existing FIS analyses throughout the study reach and adjustments made as deemed necessary to calibrate to the FIS data.

   A comparison of the uncertainty between the two levels of detail for the HEC-RAS models will be estimated using high water marks and existing gage data. This will entail calculating the standard deviations for the two model accuracies and incorporating the uncertainties associated with both map accuracies.

4. **Developed Conditions.** Using the calibrated HEC-RAS model, water surface elevations will be calculated for regulated conditions and water surface profiles will be plotted for the 10-, 100-, and 500-year flood events for the study reach (all 450 miles). Flooded area boundaries will be plotted for the entire study area (all 450 miles) for the 100-year and 500-year flood events using HEC-GeoRAS and ArcView.

5. **Floodway Analysis.** A floodway will be computed for the detailed study area using equal conveyance reduction and following Montana floodplain regulations. These regulations will be verified with the State prior to starting the analysis. The floodway boundaries will be plotted for detailed study reaches (about 92 miles) in the study area using ArcView and the extension HEC-GeoRAS. The GIS shape files will be provided as a study product for the detailed study area. In addition, a floating ice analysis will be done to provide a 100-year ice affected profile and flood boundary. The ice thickness will be based on ice thickness measurements recorded in the study area. Actual ice jam analysis for the detailed FEMA study reaches will not be done, except in the Dawson County/Glendive reach where historic and model data currently exists. The task does include the public meetings and preparation of notebook and paperwork for submission to FEMA as a Flood Insurance Study. These plates will not be included in the final Feasibility Study Report.

6. **Undeveloped Conditions.** The undeveloped conditions task will consist of two parts. The first part is to analyze the effect of man-made structures and encroachments on the Yellowstone River hydraulic profiles and flood boundaries. This will be done by removing bridges and levees from the model and calculating water surface profiles and flood inundation maps for an "undeveloped" condition for representative study reaches including those analyzed for flood insurance purposes. The same existing conditions flows will be used in the developed conditions and the undeveloped conditions hydraulic models. Using the same flow will allow comparison for the direct impacts of structures located in the flood plain on the river hydraulics independent of flow changes.

   The second part is to analyze the effect of man-made storage, diversions, and depletions on the Yellowstone River hydraulic profiles and flood boundaries. This will be done by using an "unregulated" flow condition and calculating water surface profiles and flood inundation maps for representative study reaches including those analyzed for flood insurance purposes. The unregulated flows will be used in the existing conditions (developed) model. Using a different flow in an otherwise identical model will allow comparison of the direct impacts of flow modifications on the river hydraulics independent of changes in the physical geometry of the flood plain and channel.

7. **Geomorphic and Biologic Studies.** For scoping purposes, it was assumed the detailed geomorphic and biology studies would have the same reaches, these reaches were separate from the detailed hydraulic reaches for flood plain mapping, and the reaches will not be continuous. For estimating purposes, it was assumed a total of approximately 100-miles of detailed reaches would be identified and modeled in support of the geomorphic and biologic studies. These reaches will be identified prior to the beginning of the hydraulic analysis. For detailed hydraulics modeling, this will require that cross sections

will be developed for these detailed reaches at a detailed spacing level (500 to 1000 feet apart). This area will have been modeled for the 10-, 50-, 100-, and 500-year flood events, but three additional discharges will be modeled (the discharges will be selected in coordination with the biologists and geomorphologists doing the studies in these reaches.). These discharges will represent areas prone to frequent flooding as determined by the flow duration analysis and will most likely be similar to a 1.5-year, 2-year, and a 5-year flood event. Additional modeling setup or channel delineation will be needed to adequately model side channel flows for these areas. Water surface profiles and flood boundaries will be plotted to determine areas frequently impacted from flooding. This information may be used to make recommendations regarding diversion or intake locations and design. Plates and GIS shape files will be provided for the specific study area (200 mile reach). For the geomorphic analysis, average flow velocities calculated by the HEC-RAS will be plotted to potentially indicate areas where velocities may indicate channel instability. For the detailed reaches, flood boundaries, depths, and velocities will be plotted for these flood events.

8. **Fish Passage.** Conceptual design will be done for fish passage at Cartersville Dam located near Forsyth. The analysis will be a conceptual look at the type of fish passage that could be provided and calculation of conceptual hydraulics for the fish passage structure. This would include developing a detailed HEC-RAS model that would be used to model various fish passage alternatives and the potential impacts to irrigation. Alternatives will be examined to try to minimize any potential impacts to irrigation. The task includes costs for the calculation of conceptual construction costs. The labor includes time for a field trip to the fish passage site. A cost has been included for working with a representative from the Bureau of Reclamation who is familiar with the Yellowstone River as well as with fish passage alternatives and design.

9. **Report Preparation.** A hydraulic analysis appendix will be prepared describing the HEC-RAS model development and assumptions made while developing the modeling. The description will include bridge modeling approaches, stream roughness value selection, and any assumptions required in modeling riverine structures. The report will also describe some of the limitations of the study and its results. The report will also include copies of the flood boundaries and water surface profiles developed during the study for representative reaches of the detailed study areas. All of the maps will be available on the State of Montana web site or a CD. Deliverables will include all of the HEC-RAS models, the flood boundary and flood depth shape files, calibration data, and plate layouts used in the report.

10. **Meetings and Coordination.** The task includes six trips for coordination in Montana as well as for internal coordination within the Omaha team. These six trips include a kick-off meeting with the TAC/Yellowstone River Council at the start of the hydraulics analysis, four interim progress meetings with the TAC/Yellowstone River Council (2 per year), and one summary of completed work meeting with TAC/Yellowstone River Council. Two site visits for modeling are also included and maybe combined with TAC/Yellowstone River Council meetings if needed. These site visits will be used to view the study area and collect needed data on bridges, dams, and other structures. The

visits will also be used to record information on vegetation cover for determining hydraulic roughness coefficients for the HEC-RAS model. The cost estimate also includes an additional six trips for coordination with local sponsors and public meetings in the development of the FEMA Flood Insurance Studies (2 trips per county).

11. Quality Assurance/Quality Control (QA/QC)

11.1 PI Quality Control (QC).
The PI will develop a Quality Control Plan (QCP) to outline review procedures for study products/deliverables. The QCP should include a description of the QC process, outline of interim review milestones, names and qualifications of reviewers, and an example of comment/issue resolution. The QCP will be submitted by the PI and approved by the Corps and TAC prior to initiation of the technical study. At the end of the study, the PI will complete a QC Report that documents the interim peer reviews (i.e. comments and responses).

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Yellowstone River Cumulative Effect Study
Hydraulic Modeling SOW Budget 19-Nov-03

	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Task 9	Task 10	Task 11	Task 12	Task 13	Total
Total Costs	**$38,781**	**$93,000**	**$115,067**	**$102,282**	**$80,472**	**$81,224**	**$122,832**	**$52,562**	**$26,323**	**$51,629**	**$22,400**	**$14,156**	**$26,000**	**$826,728**
USCOE Labor,Benefits,Indirect	$11,281	$0	$115,067	$102,282	$80,472	$81,224	$120,332	$37,562	$26,323	$46,629	$12,400	$0	$0	$633,572
USCOE direct costs (per diem)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$14,156	$26,000	$40,156
local communities along river	$10,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$10,000
DNRC Labor, Benefits, Indirect, ODC	$7,500	$0	$0	$0	$0	$0	$2,500	$0	$0	$5,000	$5,000	$0	$0	$20,000
MDT Labor, Benefits, Indirect, ODC	$10,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$10,000
USBR Labor, Benefits, Indirect, ODC	$0	$0	$0	$0	$0	$0	$0	$15,000	$0	$0	$0	$0	$0	$15,000
USGS Labor, Benefits, Indirect, ODC	$0	$93,000	$0	$0	$0	$0	$0	$0	$0	$0	$5,000	$0	$0	$98,000
Non-Federal Cost Share	**$27,500**	**$0**	**$0**	**$0**	**$0**	**$0**	**$2,500**	**$0**	**$0**	**$5,000**	**$5,000**	**$0**	**$0**	**$40,000**
DNRC Labor, Benefits, Indirect Cost Share	$7,500	$0	$0	$0	$0	$0	$2,500	$0	$0	$5,000	$5,000	$0	$0	$20,000
MDT Labor, Benefits, Indirect Cost Share	$10,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$10,000
local communities along river	$10,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$10,000
YRCDC Cash	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Federal Cost	**$11,281**	**$93,000**	**$115,067**	**$102,282**	**$80,472**	**$81,224**	**$120,332**	**$52,562**	**$26,323**	**$46,629**	**$17,400**	**$14,156**	**$26,000**	**$786,728**

Task Descriptions	**Deliverables**
1 Research high water mark, ice, bridge info	see ACOE project management plan - includes DNRC research on HWM; MDT for locating and producing 1997 flood photos; and MDT research on bridge specifications, also local inkind for researching flood data i
2 Additional data collection	see ACOE project management plan - USCOE direct cost includes match with USGS ($93K) under coop agreement for survey work
3 HEC-RAS model Set-up	see ACOE project management plan - Includes direct costs associated with processing and digitizing 1997 flood photos
4 Developed Conditions	see ACOE project management plan
5 Floodway Analysis	see ACOE project management plan
6 Undeveloped Conditions	see ACOE project management plan
7 Geomorphic and Biologic Studies Modeling	see ACOE project management plan - includes 100 hrs DNRC coordination and involvement
8 Fish Passage Evaluation	see ACOE project management plan
9 Report Preparation	see ACOE project management plan
10 Meetings & Coord (Corps' internal, external & public)	Corps attendance and participation at meetings (internal, MT, and FIS) - includes, DNRC time associated with MT and FIS meetings
11 Quality Control Reviews	Corps QA/QC - includes USGS and DNRC review time
12 General Expenses	see ACOE project management plan
13 Travel	see ACOE project management plan - 2 5-day site visits, 6 2-day TAC meetings, 6 2-day county FIS meetings (1 initial or interim & 1 final per county)

n FEMA reaches

Yellowstone River Cumulative Effects Study
Geomorphology SOW Budget 12-Jan-04

	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Task 9	Task 10	Task 11	Task 12	Total
Total Costs	**$11,600**	**$32,500**	**$12,500**	**$60,500**	**$21,000**	**$20,500**	**$21,000**	**$14,000**	**$14,000**	**$10,000**	**$16,000**	**$4,000**	**$237,600**
Contract Labor, Benefits, ODC	$3,000	$15,000	$3,000	$57,500	$18,000	$15,000	$18,000	$9,000	$9,000	$10,000	$6,000	$3,000	$166,500
USCOE labor, benefit, indirect, ODC	$7,600	$17,500	$500	$500	$500	$500	$500	$4,000	$4,000	$0	$9,000	$0	$44,600
DNRC Labor, Benefits, Indirect, ODC	$1,000	$0	$9,000	$2,500	$2,500	$5,000	$2,500	$1,000	$1,000	$0	$1,000	$1,000	$26,500
YRCDC Cash	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Non-Federal Cost Share	**$1,000**	**$0**	**$9,000**	**$2,500**	**$2,500**	**$5,000**	**$2,500**	**$1,000**	**$1,000**	**$0**	**$1,000**	**$1,000**	**$26,500**
DNRC Labor,Benefits, Indirect, ODC	$1,000	$0	$9,000	$2,500	$2,500	$5,000	$2,500	$1,000	$1,000	$0	$1,000	$1,000	$26,500
YRCDC Cash	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Federal Cost	**$10,600**	**$32,500**	**$3,500**	**$58,000**	**$18,500**	**$15,500**	**$18,500**	**$13,000**	**$13,000**	**$10,000**	**$15,000**	**$3,000**	**$211,100**

Task Descriptions	Deliverables
1 Review Recon Geomorphic Report	contractor = 40 hrs @ 75/hr; DNRC = 40 hrs @ 25/hr; USCOE = 15 days? (Don's spreadsheet)
2 Planform Changes	USCOE = 25 days? (Don's spreadsheet)
3 Timeline Development	Includes mapping two sets of historic channel and floodplain training structures (360 hrs); contractor = 40 hrs.
4 Morphology/Stability Analysis	Includes 100 hrs DNRC sed data collection fieldwork
5 Channel Evolution	Includes 100 hrs DNRC
6 Human Impacts	see PMP - Appendix A - includes 200 hrs DNRC involvement
7 Report Preparation	includes 200 hrs DNRC for contract management and report review
8 Meetings & Coordination	See PMP - Appendix A
9 QA/QC	Calculated as 6% of contracted services - includes 40 hrs DNRC involvement
10 General Expenses	supervision, administration, GIS software, hardware, databases and CAD resources
11 Travel and Coordination	See PMP - Appendix A
12 Delverables	See PMP - Appendix A

Note - Contract labor = $75 per hour; USCOE labor = $100 per hour; DNRC labor = $25 per hour

* cumulative effects analysis support is not included herein, but is included in the Cumulative Effects Analysis (11.0) portion of the work plan

10.0 CHANNEL AND FLOODPLAIN: GEOMORPHIC ANALYSIS [07-JAN-2004] (final rev. 1)

PURPOSE

The primary purpose of the Phase 2 geomorphology task is to assess the fluvial geomorphology of selected reaches of the Yellowstone River to determine how channel behavior is related to both natural processes and human impacts. The Phase 1 geomorphic reconnaissance was contracted as a separate scope of work, and is currently underway. The objectives of the Phase 1 reconnaissance study are to develop a baseline ArcView GIS database, and to segment the river into discrete reaches based on an appropriate classification scheme. As part of the Phase 1 geomorphic reconnaissance, a series of representative reaches will be identified for further detailed analysis. The primary objective of the Phase 2 geomorphic analysis is a detailed assessment of the geomorphic processes characteristic of each representative reach, including a relative channel stability assessment, and an evaluation of rates and trends of geomorphic evolution. These geomorphic trends will be assessed with respect to both observed hydrologic changes, and identified river controls (i.e. flood plain encroachments, bank stabilization, grade controls, etc.). Finally, the Phase 2 geomorphic analysis will attempt to quantify impacts/changes due to future development scenarios.

The following questions will be addressed during the Phase 2 geomorphic study:

1. What are the specific historic patterns and rates of channel change within each representative subreach? What human impacts can be identified, and what are their trends in location and extent? How do geomorphic trends relate to human impacts? Which subreach types are characterized by rapid channel changes, and why?

2. What are sediment substrate and transport characteristics within representative subreaches? What is the relative channel stability, and what are the controlling factors in channel stability? Is relative stability related to reach type?

3. What flow regimes are necessary to effect rapid channel changes? How has channel form and function been affected by changes in flow regime from climate changes, water development, and changes in land use? What hydrologic conditions will maintain a naturally functioning alluvial channel? Are there any thresholds beyond which the channel and floodplain form and function become degraded?

4. What is the role of naturally occurring erosion in maintaining geomorphic complexity? How do human impacts alter patterns of erosion, deposition, woody debris recruitment, and overall channel stability? What are the implications of continued trends of river development?

These questions were used in determining the primary tasks outlined in this scope of work. The following paragraphs provide a description of these tasks and how they relate to the study purposes and questions.

RELATIONSHIP TO OTHER STUDY EFFORTS

The Phase 2 geomorphic analysis is closely related to both the hydrologic and hydraulic analyses. The hydrologic analysis will provide the necessary framework for assessing geomorphic response to both natural and anthropogenic changes in flow regime. Results of the hydraulic analysis will be utilized to assess channel/floodplain relationships, as well as to assess sediment mobility and relative channel stability. The Phase 2 geomorphic analysis can be performed concurrently with biological studies, but will require results of the hydrology and hydraulic analyses.

STUDY TASKS

In Phase 2, the representative reaches will be evaluated in detail in terms of geomorphic processes and the role of human influence in channel behavior. The objectives of the detailed geomorphic analysis will: document historic planform changes and overall channel evolution, assess sediment transport conditions and channel stability, and, as possible, ascertain the effects of human influences on sediment transport, channel stability, and geomorphic evolution.

1. Review of Phase I Geomorphic Analysis

This task involves review of the Phase I geomorphic characterization and classification performed by the Contractor.

2. Planform Changes

This task involves identifying and quantifying historic plan form changes for the selected subreaches. This will be achieved by digitizing channel position from three sets of aerial photographs (1 current, and 2 historic), and incorporating that information into the GIS to determine patterns and rates of lateral channel migration and/or avulsion. Rates of channel migration will be quantified for each subreach. Site-specific consideration of anomalies and individual significant changes will be evaluated with supplemental information where available on a site-by-site basis.

3. Human Impacts Timeline

For each subreach, specific human impacts that have potentially affected geomorphic processes will be incorporated into a subreach-specific timeline for use in determining cumulative effects of human impacts on river geomorphology.

4. Channel Morphology/Stability Assessment

4.1 <u>Field Investigation/Sediment Data Collection</u>

A field investigation of each representative subreach will be performed. The field investigation will include mapping of geomorphic features such as bank erosion, pool/riffle sequences, and large woody debris aggregates. Up to 4 bar and riffle sediment gradations will be collected on the upstream portions of the individual bar sufaces within each reach. The sediment gradations will be determined by pebble count where material is sufficiently coarse, and by sieve analysis in fine-grained reaches. Human influences, such as erosion control installations, diversions, bridges, dikes, etc. will be documented and mapped. Natural erosion patterns will be assessed with respect to bar distributions and geomorphic complexity. All mapping results will be compiled into the GIS database. Field indicators of channel instability will be recorded, and, as possible, measured (e.g., exposed bridge footings).

4.2. Morphologic Assessment/Historic Channel Change

Changes in channel profile will be estimated through the acquisition and comparison of available channel cross section/stage information in representative reaches. Channel bathymetry obtained for this project will be available as a basis of comparison. The availability of historic cross section data is currently unknown, and the potential for acquiring such data should be determined by contacting entities such as the Corps of Engineers, Conservation Districts, and Montana Department of Transportation.

4.3. Obtain Sediment Gradations

Sediment gradations will be derived from gage records, literature sources, and the field investigation. This will include both pebble count and sieve data from bar surfaces. All gradations should be described in terms of the geomorphic environment in which they were collected, sampling methods, and means of determining gradations (sieve or pebble count). These sediment gradations will be analyzed with respect to grain size distributions for use in sediment mobility assessments.

4.4. Incipient Mobility Analysis

A general assessment of sediment transport competency for a range of flow conditions will be performed for each representative subreach. The intent of the competency estimations is to develop a means of comparing sediment transport capacities among a range of reach types, and to correlate transport conditions to channel form. The competency estimates will be performed using basic at-a-station hydraulics, rather than the HEC-RAS step backwater model. As such, it will be necessary to select sites that have low potential for extensive backwatering at high flows. The information required for the competency estimates include: sediment gradations, channel cross-section, channel slope, and a series of return interval discharges. Within each subreach, a series of representative cross-sections will be identified. The at-a-station hydraulics of the section will be evaluated for a range of flow conditions including bankfull, (Qbf), 2-yr, 5-yr, 10-yr, and 100-yr discharges using standard software such as WinXSPRO or SAM. The sediment gradation mobilized at each flow will be estimated based on incipient mobility calculations (e.g., Shield's parameter).

These results will be stratified with respect to reach type to assess trends in sediment capacities.

5. **Channel Evolution**
Results of the previous tasks will be integrated to assess the geomorphic evolution of the selected reaches. The channel evolution assessment will identify and, as possible, quantify the temporal and spatial changes that have occurred in the reaches. This information will be incorporated into the following task (Human Impacts Assessment), as well as the cumulative effects assessment component of the project.

6. **Human Impacts Assessment**
The human impacts assessment will consist of a compilation of results of the geomorphic analysis and evaluation of those results with respect to identified magnitudes and extents of human disturbance. The primary objectives of the task are to identify cause and effect relationships between anthropogenic impacts and channel behavior. General cause and effect relationships determined for each reach will be considered with respect to similar impact/response relationships within similar reach types.

7. **Technical Report**
A technical report will be assembled that will describe the methodologies employed, results developed, and conclusions reached. The report will include the incorporation of appropriate data into the GIS. A draft report will be delivered to the Council and the Corps for review, followed by submittal of a final report with reviewer comments addressed.

8. **Meetings and Coordination**
This task will include in-house meetings with the study team as well as meetings with the Yellowstone River Conservation District Council. It is anticipated that there will be at least six meetings with the Council during the course of the study.

9. **Quality Assurance/Quality Control (QA/QC)**

9.1 <u>PI Quality Control (QC)</u>.
The PI will develop a Quality Control Plan (QCP) to outline review procedures for study products/deliverables. The QCP should include a description of the QC process, outline of interim review milestones, names and qualifications of reviewers, and an example of comment/issue resolution. The QCP will be submitted by the PI and approved by the Corps and TAC prior to initiation of the technical study. At the end of the study, the PI will complete a QC Report that documents the interim peer reviews (i.e. comments and responses).

9.2 <u>Quality Assurance (QA)</u>.
A QA review will be performed to ensure that the PI has met the objectives of the scope and has followed the approved QCP. The QC Report will be

reviewed to insure that all comments have been addressed. This QA review will be conducted by the Corps and the TAC.

10.General Expenses

10.1 Supervision and Administration.
This task includes supervision of the employees working on the study, and administration cost such as contract management, clerical support, etc.

10.2 GIS and CADD Cost.
These cost include the direct cost of accessing various GIS software, hardware and databases, and the use of CADD resources such as workstations, printers, and plotters.

11. Travel and Coordination

This item includes travel and per diem cost for attending four TAC meeting, preparation for these meeting, and completion of follow-up tasks after each meeting. Also, included are the cost of coordinating geomorphic study tasks with other study tasks (hydrology, hydraulics, biological, etc.).

12. Deliverables

The following items will be delivered to the Council and the Corps.

- Draft and final technical reports as described in task number 7. The reports will be provided in both hard copy and electronic format.
- All models, spreadsheet, computations sheets, GIS data, etc that is complied, generates or develop through the completion of the study.
- A complete copy of the project file. This includes copies of telephone conversation logs, relevant administrative documents, meeting minutes, etc.
- A copy of all reference material used to complete the study. This will include cited literature, listing of data repositories, etc.
- A copy of the QC Report.

13.Cumulative Effects Analysis Support

Completion of the overall study will require integration of the geomorphic analysis results into the cumulative effects analysis. The geomorphology team will participate in an interdisciplinary effort aimed at understanding the cumulative effects of human and natural influences within the riparian corridor on the river. In conjunction with the interdisciplinary team, this work will include an effort to identify management/mitigation opportunities that could minimize negative impacts of human influence on river function, or improve existing conditions. The cost of this work item is included in the Cumulative Effects Analysis (Section 11.0) portion of the work plan.

10.0 Channel and Floodplain Mapping: Geomorphology (11/25/2003)

PURPOSE

The primary purpose of the Phase 2 geomorphology task is to assess the fluvial geomorphology of selected reaches of the Yellowstone River to determine how channel behavior is related to both natural processes and human impacts. The Phase 1 geomorphic reconnaissance was contracted as a separate scope of work, and is currently underway. The objectives of the Phase 1 reconnaissance study are to develop a baseline ArcView GIS database, and to segment the river into discrete reaches based on an appropriate classification scheme. As part of the Phase 1 geomorphic reconnaissance, a series of representative reaches will be identified for further detailed analysis. The primary objective of the Phase 2 geomorphic analysis is a detailed assessment of the geomorphic processes characteristic of each representative reach, including a relative channel stability assessment, and an evaluation of rates and trends of geomorphic evolution. These geomorphic trends will be assessed with respect to both observed hydrologic changes, and identified river controls (i.e. flood plain encroachments, bank stabilization, grade controls, etc.). Finally, the Phase 2 geomorphic analysis will attempt to quantify impacts/changes due to future development scenarios.

The following questions will be addressed during the Phase 2 geomorphic study:

1. What are the specific historic patterns and rates of channel change within each representative subreach? What human impacts can be identified, and what are their trends in location and extent? How do geomorphic trends relate to human impacts? Which subreach types are characterized by rapid channel changes, and why?

2. What are sediment substrate and transport characteristics within representative subreaches? What is the relative channel stability, and what are the controlling factors in channel stability? Is relative stability related to reach type?

3. What flow regimes are necessary to effect rapid channel changes? How has channel form and function been affected by changes in flow regime from climate changes, water development, and changes in land use? What hydrologic conditions will maintain a naturally functioning alluvial channel? Are there any thresholds beyond which the channel and floodplain form and function become degraded?

4. What is the role of naturally occurring erosion in maintaining geomorphic complexity? How do human impacts alter patterns of erosion, deposition, woody debris recruitment, and overall channel stability? What are the implications of continued trends of river development?

These questions were used in determining the primary tasks outlined in this scope of work. The following paragraphs provide a description of these tasks and how they relate to the study purposes and questions.

RELATIONSHIP TO OTHER STUDY EFFORTS

The Phase 2 geomorphic analysis is closely related to both the hydrologic and hydraulic analyses. The hydrologic analysis will provide the necessary framework for assessing geomorphic response to both natural and anthropogenic changes in flow regime. Results of the hydraulic analysis will be utilized to assess channel/floodplain relationships, as well as to assess sediment mobility and relative channel stability. The Phase 2 geomorphic analysis can be performed concurrently with biological studies, but will require results of the hydrology and hydraulic analyses.

PROPOSED STUDY TASKS

In Phase 2, the representative reaches will be evaluated in detail in terms of geomorphic processes and the role of human influence in channel behavior. The objectives of the detailed geomorphic analysis will: document historic planform changes and overall channel evolution, assess sediment transport conditions and channel stability, and, as possible, ascertain the effects of human influences on sediment transport, channel stability, and geomorphic evolution.

1. Review of Phase I Geomorphic Analysis

This task involves review of the Phase I geomorphic characterization and classification performed by the Contractor.

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3. Human Impacts Timeline

For each subreach, specific human impacts that have potentially affected geomorphic processes will be incorporated into a subreach-specific timeline for use in determining cumulative effects of human impacts on river geomorphology.

4. Channel Morphology/Stability Assessment

4.1 <u>Field Investigation/Sediment Data Collection</u>

A field investigation of each representative subreach will be performed. The field investigation will include mapping of geomorphic features such as bank erosion, pool/riffle sequences, and large woody debris aggregates. Up to 4 bar and riffle sediment gradations will be collected on the upstream portions of the individual bar sufaces within each reach. The sediment gradations will be determined by pebble count where material is sufficiently coarse, and by sieve analysis in fine-grained reaches. Human influences, such as erosion control installations, diversions, bridges, dikes, etc. will be documented and mapped. Natural erosion patterns will be assessed with respect to bar distributions and geomorphic complexity. All mapping results will be compiled into the GIS database. Field indicators of channel instability will be recorded, and, as possible, measured (e.g., exposed bridge footings).

4.2. <u>Morphologic Assessment/Historic Channel Change</u>

Changes in channel profile will be estimated through the acquisition and comparison of available channel cross section/stage information in representative reaches. Channel bathymetry obtained for this project will be available as a basis of comparison. The availability of historic cross section data is currently unknown, and the potential for acquiring such data should be determined by contacting entities such as the Corps of Engineers, Conservation Districts, and Montana Department of Transportation.

4.3. <u>Obtain Sediment Gradations</u>

Sediment gradations will be derived from gage records, literature sources, and the field investigation. This will include both pebble count and sieve data from bar surfaces. All gradations should be described in terms of the geomorphic environment in which they were collected, sampling methods, and means of determining gradations (sieve or pebble count). These sediment gradations will be analyzed with respect to grain size distributions for use in sediment mobility assessments.

4.4. <u>Incipient Mobility Analysis</u>

A general assessment of sediment transport competency for a range of flow conditions will be performed for each representative subreach. The intent of the competency estimations is to develop a means of comparing sediment transport capacities among a range of reach types, and to correlate transport conditions to channel form. The competency estimates will be performed using basic at-a-station hydraulics, rather than the HEC-RAS step backwater model. As such, it will be necessary to select sites that have low potential for extensive backwatering at high flows. The information required for the competency estimates include: sediment gradations, channel cross-section, channel slope, and a series of return interval discharges. Within each subreach, a series of representative cross-sections will be identified. The at-a-station hydraulics of the section will be evaluated for a range of flow conditions including bankfull, (Qbf), 2-yr, 5-yr, 10-yr, and 100-yr discharges using standard software such as WinXSPRO or SAM. The sediment gradation mobilized at each flow will be estimated based on incipient mobility calculations (e.g., Shield's parameter).

These results will be stratified with respect to reach type to assess trends in sediment capacities.

5. Channel Evolution
Results of the previous tasks will be integrated to assess the geomorphic evolution of the selected reaches. The channel evolution assessment will identify and, as possible, quantify the temporal and spatial changes that have occurred in the reaches. This information will be incorporated into the following task (Human Impacts Assessment), as well as the cumulative effects assessment component of the project.

6. Human Impacts Assessment
The human impacts assessment will consist of a compilation of results of the geomorphic analysis and evaluation of those results with respect to identified magnitudes and extents of human disturbance. The primary objectives of the task are to identify cause and effect relationships between anthropogenic impacts and channel behavior. General cause and effect relationships determined for each reach will be considered with respect to similar impact/response relationships within similar reach types.

7. Technical Report
A technical report will be assembled that will describe the methodologies employed, results developed, and conclusions reached. The report will include the incorporation of appropriate data into the GIS. A draft report will be delivered to the Council and the Corps for review, followed by submittal of a final report with reviewer comments addressed.

8. Quality Assurance/Quality Control (QA/QC)

8.1 PI Quality Control (QC).

The PI will develop a Quality Control Plan (QCP) to outline review procedures for study products/deliverables. The QCP should include a description of the QC process, outline of interim review milestones, names and qualifications of reviewers, and an example of comment/issue resolution. The QCP will be submitted by the PI and approved by the Corps and TAC prior to initiation of the technical study. At the end of the study, the PI will complete a QC Report that documents the interim peer reviews (i.e. comments and responses).

8.2 Quality Assurance (QA).

A QA review will be performed to ensure that the PI has met the objectives of the scope and has followed the approved QCP. The QC Report will be reviewed to insure that all comments have been addressed. This QA review will be conducted by the Corps and the TAC.

9.General Expenses

9.1 Supervision and Administration.

This task includes supervision of the employees working on the study, and administration cost such as contract management, clerical support, etc.

9.2 GIS and CADD Cost.

These cost include the direct cost of accessing various GIS software, hardware and databases, and the use of CADD resources such as workstations, printers, and plotters.

10. Travel and Coordination

This item includes travel and per diem cost for attending four TAC meeting, preparation for these meeting, and completion of follow-up tasks after each meeting. Also, included are the cost of coordinating geomorphic study tasks with other study tasks (hydrology, hydraulics, biological, etc.).

11. Deliverables

The following items will be delivered to the Council and the Corps.

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12.Cumulative Effects Analysis Support

Completion of the overall study will require integration of the geomorphic analysis results into the cumulative effects analysis. The geomorphology team will participate in an interdisciplinary effort aimed at understanding the cumulative effects of human and natural influences within the riparian corridor on the river. In conjunction with the interdisciplinary team, this work will include an effort to identify management/mitigation opportunities that could minimize negative impacts of human influence on river function, or improve existing conditions. The cost of this work item is included in the Cumulative Effects Analysis (Section 11.0) portion of the work plan.